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RESEARCH PAPER

Comparative analysis of woody species diversity in church, community, and national park forests in Ethiopia: Review

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Abstract. Forest resources in Ethiopia are facing intensive degradation and deforestation due to agricultural land expansion, overgrazing, urbanization, invasive species, and climate change. Due to this, small isolated forest patches are left in different parts of the country through legal protections and religious sanctions. The study aimed to examine the country's highest woody species diversity among church, community, and national park forests. The remnant forest patches in Ethiopia were categorized into church, community, and national park forests based on ownership and management objectives of the forest. The diversity data were collected from a detailed review of published and unpublished scientific reports. The variation in species richness, evenness, and Shannon diversity among forest categories were analyzed and tested using ANOVA. The mean Shannon diversity of church, community, and national park forests were 2.95, 2.88, and 3.13, respectively. These forest categories have a considerable role in species diversity in the country. However, the variation was statistically insignificant at a 95% confidence interval. Hence, each forest category plays a comparable role in woody species diversity in the country.

Keywords: Church forest diversity; Community Forest diversity; National Park Forest diversity; Woody species diversity

1. Introduction

Ethiopia is located in the Horn of Africa (Siraj et al., 2016). The country is an important regional center for biological diversity due to its wide ranges of altitude and topography (Mekuria & Shibru, 2018), as well as a rich mix of ethnic, religious, and cultural groups. The resultant rich bio-cultural diversity derived from the complex interdependence and co-adaptive processes between people and environment (Doffana, 2014). This helps the emergence of wide ranges of habitats that are suitable for the evolution and survival of various plant and animal species (Mekuria & Shibru, 2018). Ethiopia is one of the top twenty-five biodiversity richest countries in the world and hosts the Eastern Afromontane and the Horn of Africa hotspots (Temesgen & Warkineh, 2020). There were around 6000 species of higher plants, of which about 10% were endemic plants in the country (Siraj et al., 2016; Temesgen & Warkineh, 2020).

Recently, the forest resources in Ethiopia are facing intensive degradation and deforestation due to agricultural land expansion, overgrazing (Gebeyehu et al., 2019), urbanization, invasive

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species, and climate change (Abich et al., 2018). They reduce species diversity and ecosystem services in the country (Gebeyehu et al., 2019). Due to this, a small isolated forest patches are left around churches (Desissa & Healey, 2016), community forests and national parks (Abich et al., 2018).

Ethiopian Orthodox Tewahedo Church (EOTC) has a long history of planting, protecting, and preserving species within its premises (Yilma & Derero, 2020). Therefore, they serve as a conservation sites and hot spots of biodiversity (Tilahun et al., 2015; Aerts et al., 2016). Similarly, community forests are important conservation areas. They are adopted and implemented for community services and biodiversity conservation. The management system follows a bottom-up approach that encourages a sense of ownership for local communities. It plays a role in safeguarding species diversity (Zerga et al., 2019). Additionally, national parks also play a considerable role in biodiversity conservation and sustaining ecosystems services (Siraj et al., 2016). These remnant forest patches are survived as a result of legal protections (Tilahun et al., 2015) and religious sanctions such as spiritual, social, and cultural taboos, rules, and customs (Bayrak & Marafa, 2017).

The author hypnotized that the highest woody species diversity might be recorded in church forests because religious beliefs have a profound impact on the community's attitudes toward protecting the natural world through their philosophy, teaching, and religious-based forest management systems (Dudley et al., 2009). The EOTC is believed to be God's house, and everything in its compound is sacred and respected (Wassie et al., 2010). Sacred sites are almost the world's oldest form of habitat protection (Dudley et al., 2009). Churches offer a historical perspective on land use and religious practices, reflecting the deep connection between local communities and their environment. In addition, the church practices legal protections and religious sanctions in the area. Therefore, church forests, which surround the church building, have been preserved for centuries and provide a living link to the past (Wassie et al., 2010). Due to this, they exhibit greater resilience to environmental stress compared to other forests. This might help church forests maintain the highest woody species diversity in the country. The aim of the study was to identify the country's highest woody species diversity among church, community, and national park forests.

2. Methodology

2.1. Site description

Ethiopia is located in the Horn of Africa between 3° and 15°N latitude and 33° and 48°E longitude (Figure 1). The country covers 1.13 million square kilometers, with a wide altitudinal variation ranging from 110 meters below sea level (b.s.l.) at Dallol to 4,620 meters above sea level (a.s.l.) at Ras Dejen Mountain (Zerga et al., 2019). Ethiopia is the third most populous country in Africa, after Egypt and Nigeria. The current population of Ethiopia is 107,331,000. About 76.8% of the population lives in rural areas (CSA, 2013). The mean annual rainfall was approximately 2,000 mm over the southwestern highlands and less than 300 mm over the southeastern and northeastern lowlands. The maximum and minimum temperatures of the country were 34.5°C and less than 0°C, respectively (Mosissa & Abraha, 2018). Include a map of Africa highlighting Ethiopia's forests.

2.2. Data collection

This study classified remnant forest patches in Ethiopia into church, community, and national park forests based on ownership and forest management objectives (Table 1). Data were gathered through a review of relevant published and unpublished scientific articles, books, and reports. A total of 246 pieces of literature were searched using keywords such as church forests diversity, community forests diversity, national park forests diversity, and woody species diversity from Scopus, Web of Science, and other indexed journals. Among these, 80 pieces of literature were selected based on their linkage, relevance to the topic, publication date, quality of the source,

methodological rigor, clarity, and accessibility. These pieces of literature were properly reviewed, and the woody species diversity data were manually collected and recorded in Microsoft Excel. Data collection was carried out between January and May 2024.

2.3. Data analysis

Woody species diversity was determined by using Shannon diversity index (H'), evenness index (*E*), and species richness (R) (Tegene et al., 2018; Sewagegn et al., 2022). These indices provide important information about each remnant forest. Shannon diversity and evenness index was computed by Equation 1 and 2, respectively. Finally, a table was used to summarize woody species diversity data for each forest category for further analysis (Appendix 1). The data were then analyzed using Microsoft Excel 2010 (for data organization, management, and basic and advanced calculations), PAST software, and SPSS software version 20. The variation in woody species diversity among church, community, and national park forests was analyzed using Analysis of Variance (ANOVA), as ANOVA is important to statistically test the mean variation among three or more independent groups. In addition, post hoc multiple comparison tests such as the Least Significant Difference (LSD) pairwise test were conducted regardless of the significance

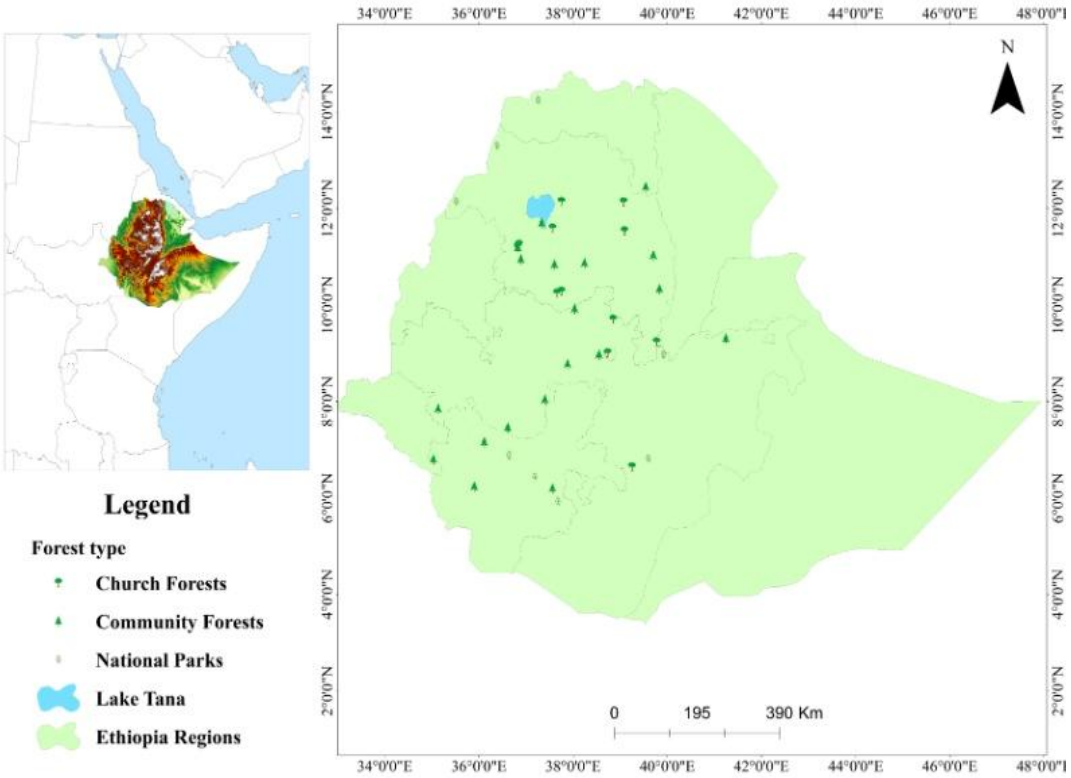

Figure 1: The distribution of reviewed church, community and national park forest in Ethiopia

Table 1: Forest categories based on ownership and management objectives

Forest type	Ownership	Management objective
Church forests	Religious institutions or churches	Preserving spiritual, cultural heritage, and sacred sites.
Community forests	Local communities or community-based organizations	Focus on balancing conservation with local needs and livelihoods.
National Park forests	National or regional government agencies	Preserving biodiversity, protecting ecosystems, and providing scientific research opportunities.

status of ANOVA, because some or all pairwise comparisons might still be significant in this case (Chen et al., 2018; Gurvich & Naumova, 2021).

$$H' = -\sum_{i=1}^{s} PiLnPi \quad (1)$$

Where H' = Shannon-Wiener diversity index, pi is proportion of individuals found in the ith species and Ln is the natural logarithm to base e (log e).

$$E = {}^{H'}/_{Hmax} \quad (2)$$

Where H'max = ln s, where s is the number of species.

3. Result and discussion

3.1. Church forest diversity

The oldest Ethiopian Orthodox Churches date back to the 4th century and are primarily situated in the northern and central highlands of Ethiopia. These churches are often surrounded by natural forests that boast a rich variety of plant and animal species (Tilahun et al. 2015). They are also important biodiversity corridors, connecting different ecological areas and supporting overall forest health. Church forests are an integral component of the church, providing sites for religious ceremonies, social gatherings, and burial grounds (Woods et al., 2016). EOTCs make a significant contribution to Ethiopia's tourism industry (Teku et al., 2024), due to the circular islands of Lake Tana, the rock-hewn churches of Tigray, the ancient temple of Yeha, and the rock-hewn churches in Lalibela.

However, most of them are adjacent cropland, rangeland, foot and livestock path networks (Klepeis et al., 2016), and grave shelters (Reynolds et al., 2017). These features have a negative association with species richness, evenness, and Shannon diversity in the church forest (Cardelus et al., 2019). However, church forests remain hotspots of plant species diversity (Tilahun et al., 2015), because, churches are believed to be the house of God and everything in its scompound is sacred and respected (Wassie et al., 2010). Furthermore, churches and church forests share a win-win relationship: the forest protects the sacredness of the church, and their associations with the church protect the forest. Many small forest patches in Ethiopia have a church at their center (Cardelus et al., 2019).

Church forests maintain a higher density of national prioritized indigenous species, including, *Juniperus procera*, *Cordia africana*, *Prunus africana*, and *Olea africana* (Wassie et al., 2010; Desissa & Healey, 2016). They also create a habitat network with other protected areas, enabling species dispersal and the survival of metapopulations (Aerts et al., 2016). Hence, church forest play a crucial role in forest conservation (Agidew & Mezgebe, 2019). According to various scientific reports, church forests maintain a large proportion of indigenous species in the country, for example selected church forests in North Gondar (Wassie et al., 2010); Tara Gedam Forest (Zegeye et al., 2011); selected church forests in Addis Ababa (Tura et al., 2016); selected church forests in North-West Ethiopia (Mequanint et al., 2020); and selected church forests in Dangila Woreda (Sewagegn et al., 2022). The conservation success is attributed taboos and social sanctions (Mosissa and Abraha, 2018), as well as the erection of walls to reduce grazing and human foot traffic (Cardelus et al., 2017).

The mean woody species richness, evenness, and Shannon diversity of church forests were 66.64, 0.74, and 2.95, respectively (Table 2). Therefore, church forests exhibited medium Shannon diversity and high species evenness. Based on the result, the Shannon diversity of church forest in Ethiopia was greater than that of the Kalfou Forest Reserve in Cameroon (Froumsia et al., 2012), but lower than that of the Strict Nature Reserve Forest in Nigeria (Adekunle et al., 2013), and tropical deciduous forests of Central India (Kumar et al., 2022). The variation might be due to agro-

ecological differences, the level of forest sacredness, and differences in forest management systems and objectives.

3.2. Community forest diversity

Ethiopia possesses diverse vegetation resources, including high forests, woodlands, bushlands, plantations, and trees outside forests. The forests comprise a vast wealth of biological resources (Zegeye et al., 2011). However, accelerated deforestation and habitat fragmentation are major environmental threats in the country, significantly reducing the capacity of forests to provide ecosystem services (Teketay, 2001). In particular, agricultural expansion and overexploitation for fuelwood, charcoal, construction materials, and timber are major factors in many tropical countries, including Ethiopia (Yakob & Fekadu, 2016). According to Food and Agricultural Organization (FAO)(2010), over 77 percent of Ethiopia's forested area disappeared between 1955 and 1979, and the country continues to lose 8% of its remaining forests annually. Hence, participatory forest management has become an important mechanism to protect forests and enhance the livelihoods of communities who use and benefit from them.

A community forest is owned, managed, and utilized by local communities or groups of people living in close proximity to the forest (Wood et al., 2019). A large proportion of rural people in Ethiopia depend on community forests for food security and livelihoods (Yami & Mekuria, 2022). These forests provide important resources and ecosystem services for local communities, such as firewood, climate regulation, beekeeping, and erosion reductions (Zerga et al., 2019). Additionally, they can enhance income and revenue through fair and equitable distribution of benefits within the communities living in the periphery of the forest (Pokhrel & Gautam, 2024). Therefore, community forests are seen as a tool to improve forest management, alleviate poverty, and promote equity. While the financial benefits are often modest, the non-monetary benefits are real and tangible (Murdiyarso & Skutsch, 2006), such as social capacity building and rural infrastructure development (Pokhrel & Gautam, 2024).

Local communities maintain forests by establishing by-laws, self-regulation (Murdiyarso & Skutsch, 2006), and legal protections. There may also be government interference in identifying diverse needs and interests to improve forest governance (Yami & Mekuria, 2022). This collaborative approach helps maintain the sustainability of the forest (Murdiyarso & Skutsch, 2006). As a result, community forests are important habitats for countless species (Zerga et al., 2019), and considerably reduce deforestation while increase regeneration (Murdiyarso & Skutsch, 2006). Hence, they play important role in biodiversity conservation and the sustainable use of natural resources (Pokhrel & Gautam, 2024).

The mean woody species richness, evenness, and Shannon diversity of community forests were 72.15, 0.77, and 2.88, respectively (Table 2). According to the result, the Shannon diversity of community forests in Ethiopia was lower than that of the Strict Nature Reserve Forest in Nigeria (Adekunle et al., 2013), the tropical deciduous forests of Central India (Kumar et al., 2022), and the Kibate National Park forest ecosystem in Uganda (Okiror et al., 2012), but greater than the Kalfou Forest Reserve in Cameroon (Froumsia et al., 2012). This variation may be attributed to

Table 2: The mean species richness, evenness, and Shannon diversity of church, community, and national park forests in Ethiopia

Forest type	Richness (R)	Evenness (E)	Shannon diversity (H')
Church forest	66.64 ± 39.49	0.74 ± 0.17	2.95 ± 0.55
Community forest	72.60 ± 25.68	0.77 ± 0.10	2.88 ± 0.43
National Park Forest	108.50 ± 70.45	0.76 ± 0.17	3.13 ± 0.93
Total	77.72 ± 43.53	0.76 ± 0.14	2.95 ± 0.58
P	0.074	0.849	0.611
F	2.820	0.165	0.499

agro-ecological difference, community perceptions, and differing forest management systems and objectives.

3.3. National park forest diversity

The vegetation resources in protected area are being highly affected due to habitat degradation, fragmentation, illegal settlement, agricultural expansion, fire, and human-wildlife conflicts (Abich et al., 2018). However, Ethiopia is among the few countries having more than 55 protected areas, including 21 national parks. National parks are forested areas designated and protected by government agencies with a focus on biodiversity conservation, research, education, recreation, and tourism. They are expanding numerically in developing countries, including Ethiopia, in recent decades (Temesgen & Warkineh, 2020), with a defined and delimited geographical area (Siraj et al., 2016). National parks are also dedicated to protecting and maintaining cultural resources and traditional attributes (Siraj et al., 2016; Abich et al., 2018). Therefore, they are important in biodiversity conservation, ecosystems functioning, and ecological processes (Girma & Maryo, 2018; Temesgen & Warkineh, 2020). In addition, national parks have made a great contribution for Ethiopia's tourism industry.

The mean woody species richness, evenness, and Shannon diversity of national park forests were 108.50, 0.76 and, 3.13 respectively (Table 2). According to the result, the mean Shannon diversity of Ethiopian national park forests was greater than W National Park in Burkina Faso (Dimobe et al., 2019), Bannerghatta National Park in India (Kakkar et al., 2021), and Banke National Park in Nepal (Napit, 2015), but lower than National Park of Sena Oura in Chad (Todou et al., 2017). The variation might be due to agro-ecological differences, management systems, and objectives.

3.4. Comparative analysis of woody species diversity among forest categories

According to the above result, the mean Shannon diversity indices among church, community, and national park forests were 2.95, 2.88, and 3.13, respectively. The variation in woody species diversity among forest categories was statistically insignificant at a 95% confidence interval (Table 2). This suggests that the difference in Shannon diversity among the forest categories was not strong enough to be considered significant in Ethiopia. However, the LSD pairwise comparison test reveals that church and community forests had a significant difference in species richness compared to national park forests, which was not captured when looking at the overall group differences (Table 3). The result was consistent with scientific reports by different scholars (Chen et al., 2018; Gurvich & Naumova, 2021). Therefore, performing pairwise comparison test seems important, regardless of the significance of ANOVA, to identify differences that might not be apparent in overall analyses (Chen et al., 2018).

Table 3. LSD comparison test of species richness, evenness, and Shannon diversity in forest categories

Dependent Variable	Pairwise comparison test	Mean difference	Std. error	Sig.
Richness(R)	A vs B	-5.509	14.846	.713
	A vs C	-41.859*	18.726	.031
	B vs C	-36.350*	17.433	.044
Evenness (E)	A vs B	-.029	.050	.570
	A vs C	-.016	.063	.796
	B vs C	.012	.059	.836
Shannon diversity (H')	A vs B	.071	.210	.737
	A vs C	-.175	.265	.512
	B vs C	-.246	.246	.324

*. The mean difference is significant at the 0.05 level.
Where, A = church forest; B= Community Forest; C = National Park forest

On the other hand, the mean woody species richness, evenness, and Shannon diversity of remnant (church, community, and national parks) forests in Ethiopia were 77.50, 0.76, and 2.95, respectively (Table 2). According to Baliton et al. (2020), the calculated Shannon diversity value can be classified very high (≥3.50), high (3.00 - 3.49), moderate (2.50 - 2.99), low (2.0 - 2.49), and very low (≤1.99) (Baliton et al., 2020). Therefore, remnant forest patches had a moderate Shannon diversity index in the country.

The mean Shannon diversity of remnant forests in Ethiopia was greater than that of Majang Biosphere Reserve (Tadese et al., 2021), and the Kalfou Forest Reserve in Cameroon (Froumsia et al., 2012); however, the result was lower than those of the Sheka and Kafa Biosphere Reserves (Tadese et al., 2021), the Strict Nature Reserve Forest in Nigeria (Adekunle et al., 2013), and tropical deciduous forests of Central India (Kumar et al., 2022). The variation might be agro-ecology, and forest management objectives.

In addition, Pearson's correlation analysis revealed that species richness and Shannon diversity had a statistically positive relationship at the 99% confidence interval. This finding is consistent with a study conducted by Yilma and Derero (2020). Hence, species richness reduction caused by anthropogenic and natural factors might reduce Shannon diversity in remnant forests of Ethiopia (Table 4).

3.5. Challenges of remnant forests in Ethiopia

Ethiopia has encountered numerous challenges in forest development and conservation, as highlighted by various studies (Wassie et al., 2010; Tilahun et al., 2015; Mekonnen et al., 2022). The country is experiencing rapid loss of habitats and species through a combination of factors, including environmental degradation, agricultural expansion, deforestation, and over-harvesting (Wassie, 2007; Cardelus et al., 2019). The decline in plant species is further exacerbated by increasing human and livestock populations, which accelerate rural poverty and the loss of biodiversity in Ethiopia (Wassie, 2007; Tilahun et al., 2015). In developing countries like Ethiopia, the growing population drives the conversion of forests into agricultural land and grazing areas and promotes the replacement of native trees with fast-growing exotic species, as well as increased timber extraction for firewood and construction purposes (Mekonnen et al., 2019; Taju et al., 2023).

4. Conclusion and Recommendation

The diverse vegetation resources of Ethiopia are highly affected by anthropogenic factors such as agricultural expansion, deforestation and habitat fragmentation. Due to this, only small remnant forest patches remain in church, community, and national park forests. They survived through legal protections and religious sanctions, and the legal framework of forest protection. These remnant forest patches are hotspots of biodiversity in the country. The results indicate that church, community, and national park forests have a moderate Shannon diversity. The highest and the lowest Shannon diversity values were recorded in national park and community forests, respectively. However, the variation among each forest category was statistically insignificant. Therefore, each remnant forest category contributes a comparable role to woody species diversity, conservation, and ecosystem services in the country.

Table 4: Pearson correlation of species richness, evenness, and Shannon diversity, density, among church, community, and national park forests in Ethiopia

Variable	Species richness (R)	Evenness (E)	Shannon diversity (H')
Species richness (R)	1		
Evenness (E)	-.080	1	
Shannon diversity (H')	.463**	.235	1

**. Correlation is significant at the 0.01 level (2-tailed).

According to the results, the following recommendations are suggested; (i) awareness creation should be provided to local communities regarding forest management and sustainable utilization; (ii) the government should provide alternative sources of energy for communities to reduce deforestation and forest degradation; (iii) integration of indigenous knowledge and modern conservation approaches should be encouraged during the forest management planning and implementation process; (iv), limited studies have been conducted on church and national park forests. Therefore, further investigation in the areas is needed.

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Appendix 1.

The mean species richness, evenness, and Shannon diversity of church, community and national park forests in Ethiopia

No	Study area	Forest type	R	E	H'	Reference
1	Selected church forests in Dangila Woreda	A	35.00	0.42	2.65	(Sewagegn et al., 2022)
2	Selected Church Forests in Addis Ababa	A	26.00	0.70	2.27	(Siraj et al., 2016)
3	South East of Lake Tana Basin	A	14.33	0.95	2.51	(Mequanint et al., 2020)
4	Yemrehane Kirstos Church Forest	A	39.00	0.79	2.88	(Abunie & Dalle, 2018)
5	Debre Libanos Church Forest	A	59.00	0.77	3.14	(Koricho et al., 2020)
6	Tara Gedam Church Forest	A	113.00	0.65	2.98	(Zegeye et al., 2011)
7	Church Forests Of Dangila	A	73.00	0.82	3.50	(Birhanu et al., 2021)
8	Sesa Mariam Monastery Forest	A	113.00	0.85	3.81	(Meshesha et al., 2015)
9	Abbo Sacred Forest	A	63.00	0.75	2.99	(Yigeremu & Woldearegay, 2022)
10	Zijji Mariam Forest	A	48.00	0.85	3.29	(Mekonnen et al., 2022)
11	Gatira Georges Forest	A	34.00	0.82	2.88	(Ayalew, 2020)
12	Aba Asrat Monastery Forest	A	120.00	0.93	3.61	(Bayeh, 2013)
13	Menfeskidus Monastery Forest	A	129.00	0.38	1.84	(Negesse & Woldearegay, 2022)
14	Gra-Kahsu Natural Vegetation	B	64.00	0.80	2.29	(Atsbha et al., 2019)
15	Doshke Forest	B	44.00	0.75	2.62	(Tegene et al., 2018)
16	Wurg Forest	B	76.00	0.90	3.38	(Boz & Maryo, 2020)
17	Kuandisha Forest	B	61.00	0.88	2.50	(Berhanu et al., 2017)
18	Kibate Forest	B	125.00	0.81	3.33	(Meragiaw et al., 2021)
19	Gura-Ferda natural forest	B	64.00	0.76	2.72	(Betemariyam, et al., 2022)
20	Ades Dry Afromontane Forest	B	65.00	0.67	2.82	(Reshad et al., 2019)
21	Kumuli Dry Evergreen Afromontane Forest	B	113.00	0.600	2.97	(Woldemariam et al., 2016)
22	Menagesha Suba State Forest	B	112.00	0.920	2.57	(Benti, 2011)
23	Keja Araba Forest	B	40 .00	0.790	2.81	(Yakob & Fekadu, 2016)
24	Tula forests	B	47.00	0.860	3.14	(Yakob & Fekadu, 2016)
25	Amoro Forest	B	57.00	0.920	3.29	(Birhanu et al., 2018)

No	Study area	Forest type	R	E	H'	Reference
26	Dry Afromontane Forests of Northern Ethiopia	B	80.00	0.730	2.80	(Muluneh et al., 2021)
27	Yegof Dry Afromontane Forest	B	76.00	0.570	2.26	(Woldearegay et al., 2018)
28	Moist Afromontane Forest of Agama	B	72.00	0.780	3.25	(Dibaba et al., 2020)
29	Weiramba Forest	B	32.00	0.660	2.30	(Teshager et al., 2018)
30	Zegie Peninsula Natural Forest	B	113.00	0.84 0	3.72	(Alelign et al., 2007)
31	Woynwuha Natural Forest	B	69.00	0.760	3.24	(Mekonen et al., 2015)
32	Managed and Community Used Forest	B	71.00	0.670	2.32	(Edae et al., 2015)
33	Wof Washa Natural Forest	B	62.00	0.800	3.25	(Fisaha et al., 2013)
34	Alitash National Park	C	24 .00	0.660	2.11	(Abich et al., 2018)
35	Awash National Park	C	52.00	0.870	1.78	(Sirbaro, 2020)
36	Kafta Sheraro National Park	C	70.00	0.770	3.20	(Temesgen & Warkineh, 2020)
37	Chebera Churcura National Park	C	106.00	0.460	3.89	(Girma & Maryo, 2018)
38	Bale Mountains National Park	C	205.00	0.810	4.34	(Muhammed & Elias, 2021)
39	Nechisar National Park	C	208.00	0.640	3.66	(Shimelse et al., 2010)
40	Godebe National Park	C	59.00	0.930	3.64	(Taju et al., 2023)
41	Maze National Park	C	144.00	0.950	2.38	(Siraj et al., 2016)
	Sum		3177.33	31.240	120.93	
	Mean		77.50	0.760	2.95	
	F		2.82	0.165	0.499	
	P		0.072	0.849	0.611	

A = Church Forest; B = Community Forest; C = National Park forests; R = Richness; E = Evenness; H' = Shannon diversity